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## Distribution, Abundance and Species Composition of Phytoplankton in the Vietnamese Waters

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### ABSTRACT

Samples of phytoplankton were collected from 58 stations in the Vietnamese waters from 30 April to 21 - May, 1999 on boat M. V. SEAFDEC. The total of 508 taxa, which consisted of 1 genus, 3 species of Cyanophyta; 1 genus, 2 species of Silicoflagellata; 63 genera, 283 species of Bacillariophyta and 34 genera, 220 species of Pyrrophyta were identified. In the Cyanophyta, *Oscillatoria* (mainly *O. erythraea*) was the frequently dominant species. *Bacteriastrium elongatum*, *Bellerochea malleus*, *Chaetoceros cintus*, *Thalassionema nitzschioides* and *Thalassiothrix frauenfeldii* were dominant species only in some stations of the coastal region of area A, B and D. Average cell numbers of phytoplankton in the different parts of Vietnamese sea waters were in the range 5.984-53.570 cells/l.

The indices of species diversity were in the ranges:

- R: from 0.70 to 2.5
- $H'$ : from 2.49 to 2.32
- $H'_{\max}$ : from 6.67 to 6.80
- J: from 0.37 to 0.48
- Dv: from 1.21 to 2.07

**Key words:** Phytoplankton, Vietnamese sea waters, species diversity indices

### Introduction

Phytoplankton in the Vietnamese waters has been collected the specimens since 1920 by Maurice Rose. He is the first scientist, who published the list of 42 species of phytoplankton in the Vietnamese coast and the Gulf of Thailand in 1926. The study surveys on the number distribution and species composition of phytoplankton were carried out in the Vietnamese waters as in 1959 -1962 was the Vietnam - China collaborative research program and in 1960 - 1961 was the Vietnam - Soviet Union collaborative research program in the Gulf of Tonkin; from 1962 to 1965 and from 1976 to 1978 were the study survey in the West of the Gulf of Tonkin; in 1978 - 1980 was the survey in the Thuan Hai - Minh Hai sea waters, etc...

The above mentioned surveys which were used the phytoplankton net with mesh size is 100 $\mu$ M.

Phytoplankton was collected by the sampling equipment of Van Dorn sampler and filtered through net of 20 $\mu$ M mesh size in this study survey. The objectives of this study were:

- To identify phytoplankton species and their distribution.
- To study phytoplankton abundance.
- To describe the diversity indices of phytoplankton.

## Materials and Methods

Phytoplankton sampling surveys were carried out on board M. V. SEAFDEC at 58 stations in the Vietnamese waters [Fig. 1] from 30 - April to 21- May, 1999.

The Vietnamese waters can be divided into four areas:

- A - The Gulf of Tonkin
- B - The Central sea waters
- C - The South - East sea waters
- D - The South - West sea water (The Gulf of Thailand)

The samples were collected by a 20 liter Van Dorn water sampler at 0m, 50m and 100m water layers.

Forty liters of water samples were filtered through a phytoplankton net which its mesh size 20µM and preserved in a 3 - 4% sea water formaline solution.

The samples were concentrated by precipitation. Cell count and identification were 0.09ml in 5 - 40ml of precipitative samples. Number of phytoplankton were calculated into cells/l. Regions with different density were drawn by defining the isoplankton. Statistical analytical indices of phytoplankton were described following the methods in Shannon - Wiener (1963).

$$H' = - \sum_{i=1}^s P_i \log P_i$$

The diversity can measure species evenness (J):

$$J = \frac{H'}{\log_2 S} = \frac{H'}{H'_{\max}} \text{ (Pillay, 1965).}$$

Value of diversity index (Dv) can also measure:

$$Dv = H' \cdot J \text{ or } \frac{H'^2}{\log_2 S} \text{ (Chen Qing Chao, 1994).}$$

The richness index (R) measured by:  $R = \frac{S}{\sqrt{n}}$

Where:  $P_i = \frac{n_i}{n}$ ;  $n_i$  = The number of individuals of the  $i$ th species;  $n$  = The total individual number;  $S$ : The total species.

## Results

### Identification

In the Vietnamese waters, the total of 508 taxa consisted of 1 genus, 3 species of Cyanophyta, 1 genus, 2 species of Silicoflagellata; 63 genera, 283 species of Bacillariophyta and 34 genera, 220 species of Pyrrophyta were identified.

The taxonomic list is given in Table 1. However, some other species of phytoplankton have not been met in this time.

The occurrence of phytoplankton species in the different areas was also given in table 1. In the Area B, which had highest species number was 387. The number of species in the area C, A, D were 320, 271, 218 respectively.

**Table 1.** The taxonomic list of phytoplankton identified at the surface layer in the different parts of Vietnamese waters(April-May, 1999).

A: The Gulf of Tonkin    +: Present  
B: The Central sea waters                                ++: Frequent  
C: The South - East sea waters                      +++: Abunda  
D: The South - West sea waters (The Gulf of Thailand)

No.	Species	A	B	C	D
	Cyanophyta				
1	<i>Oscillatoria erythraea</i> (Ehrenberg) Geitler	+++	+++	+++	+++
2	<i>O. contortum</i> Wille	++	++	+	+
3	<i>O. thiebautii</i> (Gem) Geitler	+	+	+	+
	<b>Silicoflagellata</b>				
4	<i>Dictyocha fibula</i> Ehrenberg	+++	+++	++	+++
5	<i>D. octonaria</i> Ehrenberg		+		
	<b>Bacillariophyta</b>				
6	<i>Achnanthes brevipes</i> Agardh	+			
7	<i>Actinopteryx crassus</i> v. Heurck		+	+	+
8	<i>A. hexagonus</i> Grunow		+		
9	<i>A. splendens</i> (Shadbolt) Ralfs	++			
10	<i>A. stella</i> v. <i>thumii</i> A Schmidt		+		
11	<i>A. trilingulatus</i> Brightwell		+	+	
12	<i>A. undulatus</i> (Bailey) Ralfs		+	+	
13	<i>Amphipleura pellucida</i> Kutzing		+		
14	<i>Amphiprora alata</i> Kutzing	+++	++	++	+++
15	<i>A. gigantea</i> Grunow v. <i>sulcata</i> (Meara) Cleve	+	+	+	+
16	<i>A. surirelloides</i> Hendey	+			
17	<i>A. sp.</i>	+			
18	<i>Amphora graeffi</i> v. <i>minor</i> Peragallo				+
19	<i>A. lineata</i> Gregory			+	
20	<i>A. ovalis</i> Kutzing	++			
21	<i>A. quadrata</i> Brebisson	+++	++	++	+++
22	<i>A. ventricosa</i> Gregory				+
23	<i>Asterionella japonica</i> Cleve	+	++	+	+
24	<i>Asterolampra grevillei</i> Wallich	+			
25	<i>A. marylandica</i> Ehrenberg	+	++	++	++
26	<i>A. vanheurckii</i> J. Brun		+		
27	<i>Asteromphalus cleveanus</i> Grunow	+	++	+	++
28	<i>A. elegans</i> Greville		+	+	
29	<i>A. flabellatus</i> (Brebisson) Greville		+	+	++
30	<i>A. heptactis</i> (Brebisson) Greville	+	+	+	
31	<i>A. robustus</i> Castracane			+	
32	<i>Bacteriastrum comosum</i> Pavillard	+++	+++	++	+++
33	<i>B. comosum</i> v. <i>hispida</i> (Castracans) Ikari	+++	+	+	+
34	<i>B. delicatulum</i> Cleve	+++	+		+
35	<i>B. elongatum</i> Cleve	+	++	+	

Table 1.(Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
36	<i>B. hyalinum</i> Lauder	+++	+++	+++	+++
37	<i>B. hyalinum</i> v. <i>princeps</i> (Castracane) Ikari		+	+	+
38	<i>B. mediterraneum</i> Pavillard	++	+		
39	<i>B. minus</i> Karsten	++	+	+	+
40	<i>B. varians</i> Lauder	+	+	++	+
41	<i>Bellerochea malleus</i> (Brightwell) v. Heurck				+
42	<i>B. indica</i> Karstein			+	
43	<i>Biddulphia aurita</i> (Lyngbye) Brebisson & Godey		+	+	
44	<i>B. dubia</i> (Brightwell) Cleve	+			++
45	<i>B. granulata</i> Roper		+		
46	<i>B. longicruris</i> Greville		++	++	+++
47	<i>B. mobiliensis</i> Bailey	+	++	+	++
48	<i>B. obsuta</i> Kutzing			+	+
49	<i>B. regia</i> (Schultze) Ostenfeld	++	+++	++	+++
50	<i>B. reticulatum</i> (Ehrenberg) Boyer		+		
51	<i>B. sinensis</i> Greville	+		+	++
52	<i>Brebissomia boeckii</i> (Ehrenberg) Grunow	+			
53	<i>Caloneis linearis</i> (Grunow) Boyer	+			
54	<i>Campyloneis grevillei</i> Grunow	+			
55	<i>Campylodiscus biangulatus</i> Greville	++	+	+	+
56	<i>C. brightwellii</i> Grunow	+			
57	<i>C. echineis</i> Ehrenberg		+		
58	<i>C. fastuosus</i> Ehrenberg		+		
59	<i>Ceratalus turgidus</i> Ehrenberg	+			
60	<i>Cerataulina bergoni</i> Pelagallo	++	+++	++	++
61	<i>C. compacta</i> Ostenfeld		++	+	++
62	<i>Chaetoceros affinis</i> Lauder	+++	+++	+++	+++
63	<i>C. affinis</i> v. <i>circinalis</i> Hustedtt	+	+	+	++
64	<i>C. affinis</i> v. <i>willei</i> Hustedtt	++	+	++	++
65	<i>C. anastomosans</i> Grunow	+			
66	<i>C. atlanticus</i> Cleve	+	++	+	
67	<i>C. atlanticus</i> v. <i>neapolitana</i> (Schroder) Hustedtt	+	+++	++	+
68	<i>C. atlanticus</i> v. <i>skeleton</i> (Schutt) Hustedtt	+	+++	++	+
69	<i>C. borealis</i> Bailey	+	+		
70	<i>C. brevis</i> Schutt	+	+		
71	<i>C. castracanei</i> Karsten	++	+++	++	+
72	<i>C. cinctus</i> Gran	+	+	+	++
73	<i>C. coartatus</i> Lauder	+++	++	++	+++
74	<i>C. compressus</i> Lauder	+++	+++	+++	+++
75	<i>C. constrictus</i> Gran		+	+	+
76	<i>C. covolutus</i> Castracane	+	+	+	
77	<i>C. costatus</i> Pavillard	+	+	+	+
78	<i>C. crinitus</i> Schutt	+++	+++	++	++

Table 1. (Continued).

No.	Species	A	B	C	D
	<b>Bacillariophyta</b>				
79	<i>C. curvisetus</i> Cleve	++	+++	+++	+++
80	<i>C. debilis</i> Cleve			+	
81	<i>C. decipiens</i> Cleve	+++	++	++	++
82	<i>C. decipiens f. singularis</i> Gran	+	+	+	++
83	<i>C. densus</i> Cleve	+++	+		
84	<i>C. denticulatus</i> Lauder	+++	+++	+++	+++
85	<i>C. didymus</i> Ehrenberg	++	+	+	++
86	<i>C. didymus v. anglica</i> (Grunow) Gran	+++	+	+	+
87	<i>C. didymus v. protuberans</i> Gran & Yendo	+			
88	<i>C. distans</i> Cleve	++	+	+	+++
89	<i>C. diversus</i> Cleve	+++	+++	+++	+++
90	<i>C. eibonii</i> Grunow	++	+	+	
91	<i>C. indicum</i> Karsten		+		+
92	<i>C. laciniosus</i> Schutt	+++	++	+	+
93	<i>C. laevis</i> Leuduger - Formorel	+++	++	++	+++
94	<i>C. lauderi</i> Ralfs	+	+		+
95	<i>C. lorenzianus</i> Grunow	+++	+++	+++	+++
96	<i>C. messanensis</i> Castracane	++	+++	+++	++
97	<i>C. muelleri</i> Lemmermann	++	+		
98	<i>C. nipponica</i> Ikari		+		
99	<i>C. paradoxus</i> Cleve	++	++	+	++
100	<i>C. pelagicus</i> Cleve	+	+	++	++
101	<i>C. pendulus</i> Karsten	+++	+++	+++	++
102	<i>C. peruvianus</i> Brightwell	++	+++	+++	+++
103	<i>C. peruvianus f. robusta</i> (Cleve) Hustedtt	++	++	++	+++
104	<i>C. pseudocurvisetus</i> Margin	++	+	+	++
105	<i>C. pseudodichaeta</i> Ikari			+	
106	<i>C. radicans</i> Schutt		++	+	
107	<i>C. rostratus</i> Lauder	++	+		
108	<i>C. seychelarum</i> Karsten	++	++	+++	++
109	<i>C. siamense</i> Ostensfeld	+		+	+
110	<i>C. similis</i> Cleve	+	+	+	
111	<i>C. simplex</i> Ostensfeld		+++	++	
112	<i>C. socialis</i> Lauder	++	+	+	+
113	<i>C. subsecundus</i> (Grunow) Hustedtt	++	+	+	++
114	<i>C. subtilis</i> Cleve	+			
115	<i>C. teres</i> Cleve	+	+	+	
116	<i>C. tetrastichon</i> Cleve	++	+	+	
117	<i>C. tortissimus</i> Gran	++	+++	+++	++
118	<i>C. vanheurcki</i> Gran	++	+		+
119	<i>C. weissflogii</i> Schutt	+	+		
120	<i>Climacodium frauenfeldianum</i> Grunow	+++	+++	+++	+
121	<i>C. bivoncavum</i> Cleve	+++	+++	+++	+++
122	<i>C. moniligera</i> Ehrenberg	+			
123	<i>Coconeis scutellum</i> Ehrenberg			+	
124	<i>Corethron hystrix</i> Hensen	+	+++	+++	++

**Table 1.** (Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
125	<i>C. pelagicum</i> Grunow	+++	++	++	+++
126	<i>Coscinodiscus argus</i> Ehrenberg		+	+	+
127	<i>C. bipartitus</i> Rattray	+	++	++	+++
128	<i>C. curvisetus</i> Cleve	+			
129	<i>C. centralis</i> Ehrenberg				+
130	<i>C. curvalutus</i> Grunow	+	+	+	+
131	<i>C. curvalutus</i> v. <i>minor</i> (Ehrenberg) Grunow		+		
132	<i>C. divisus</i> Grunow	+			+
133	<i>C. excentricus</i> Ehrenberg	++	+++	++	+
134	<i>C. granii</i> Grouh			+	
135	<i>C. janischii</i> A. Schmidt	++	+		+
136	<i>C. jonesianus</i> Ostenfeld	+	++	+	+++
137	<i>C. lineatus</i> Ehrenberg	++	++	++	+
138	<i>C. marginatus</i> Ehrenberg	++	++	++	++
139	<i>C. oculatus</i> (Fauv.) Petit	+	+	++	+++
140	<i>C. oculus-iridis</i> Ehrenberg	+++	++	++	++
141	<i>C. radiatus</i> Ehrenberg	+++	+++	++	+
142	<i>C. sub-buliens</i> Jorgensen		+	+	
143	<i>C. subtilis</i> Ehrenberg	+	+	++	+++
144	<i>C. spinosus</i> Chin				+
145	<i>C. thorii</i> Pavillard	++	++	++	++
146	<i>C. wailesii</i> Gran & Angst	+			+
147	<i>Cymbella naviculiformis</i> Auerswald	+			
148	<i>C. turgida</i> (Greg) Cleve		+	+	
149	<i>C. ventricosa</i> Kutzing	+	+		
150	<i>Cyclotella stylorum</i> Brightwell	+	+		
151	<i>Dactyliosolen mediterraneus</i> Peragallo	+++	+++	+++	+++
152	<i>Denticula</i> sp.	+			
153	<i>Diploneis bombus</i> Ehrenberg	+++	++	++	++
154	<i>D. crabro</i> Ehrenberg				++
155	<i>D. elliptica</i> (Kutzing) Cleve				+
156	<i>D. fusca</i> (Gregory) Cleve			+	
157	<i>D. lineata</i> (Donkin) Cleve		+		
158	<i>D. notabilis</i> (Grevill) Cleve			+	
159	<i>Ditylum brightwellii</i> (West) Grunow	+++	++	+	+
160	<i>D. sol</i> Grunow	+++	+++	++	+++
161	<i>Donkinia rectatifer</i> v. <i>intermedia</i> Donkin	+++	+	+	++
162	<i>Eucampia cornuta</i> (Cleve) Grunow	++	++	++	++
163	<i>E. zodiacus</i> Ehrenberg	++	+	+	+
164	<i>Fragilaria construens</i> (Ehrenberg) Grunow		+	++	
165	<i>F. crotonensis</i> Kitton			+	+
166	<i>Guinardia flaccida</i> (Castracane) Peragallo	+++	+++	+++	+++
167	<i>Gossleriella tropica</i> Schutt	+	++	++	

**Table 1.** (Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
168	<i>Gyrosigma balticum</i> Ehrenberg	+	+	++	+++
169	<i>G. spenceri</i> (Quekett) Cleve	++	++	++	+++
170	<i>G. strigile</i> Smith	+	+	+	
171	<i>G. wansbeckii</i> (Donkin) Cleve		+		
172	<i>Grammtophora marina</i> (Lyngbye)	+			
173	<i>G. undulata</i> Ehrenberg		+		
174	<i>Hemiaulus hauckii</i> Grunow	+++	+++	+++	+++
175	<i>H. indicus</i> Karsten	+	++	+	++
176	<i>H. membranacea</i> Cleve	+++	++	+	+
177	<i>H. sinensis</i> Greville	+++	+++	+++	+++
178	<i>Hemidiscus cuneiformis</i> Wallich	+	+	+	+
179	<i>H. hardmannianus</i> (Greville) Mann	+	+	+	++
180	<i>Lauderia borealis</i> Gran	++	++	+++	++
181	<i>Leptocylindrus danicus</i> Cleve	+++	++	++	+++
182	<i>Mastogonia heptagona</i> Ehrenberg			+	
183	<i>Mestogloia minuta</i> Greville	+			
184	<i>Melosira distans</i> v. <i>lirata</i> (Ehrenberg) Bethge	+			
185	<i>M. juergensi</i> Agardh		+	+	
186	<i>M. mummuloides</i> (Dillw.) Agardh		+		
187	<i>M. sulcata</i> (Ehrenberg) Cleve	+	+	+	
188	<i>Navicula atlantica</i> Schmidt				+
189	<i>N. cancellata</i> Donkin	+		+	
190	<i>N. barberi</i> Barber	+			+
191	<i>N. crucigera</i> (W. Smith) Cleve	++	+		
192	<i>N. cruciloides</i> Brockmann		+	+	
193	<i>N. directa</i> v. <i>remota</i> Cleve		+		
194	<i>N. elegans</i> W. Smith	+	+		
195	<i>N. forcipata</i> Greville			+	
196	<i>N. granii</i> Jorgensen	+			
197	<i>N. hennedyii</i> W. Smith				+
198	<i>N. lanceolata</i> W. Smith	+			
199	<i>N. linearis</i> (Grunow) Boyer	+			
200	<i>N. marina</i> Ralf		+		
201	<i>N. membranacea</i> Cleve	++	++	+	+++
202	<i>N. menaiana</i> Hendey		+		
203	<i>N. rostellata</i> Kutzing		+		
204	<i>N. septentrionalis</i> (Grunow)	+			
205	<i>N. tuscula</i> (Ehrenberg) Van Heurck			+	
206	<i>N. vanhoeffenii</i> Gran		+		
207	<i>Nitzschia angularis</i> Smith		+		
208	<i>N. bilobata</i> Smith		+		
209	<i>N. closterium</i> Smith			+	
210	<i>N. delicatissima</i> Cleve	+++	+++	++	+

**Table 1.** ( Continued).

No.	Species	A	B	C	D
	Bacillariophyta				
211	<i>N. frigida</i> Grunow		+	+	++
212	<i>N. longissima</i> (Breb.) Ralfs	+++	+++	++	+++
213	<i>N. lorenziana</i> Grunow		+		+
214	<i>N. paradoxa</i> (Gmelin) Grunow	++	++	++	+++
215	<i>N. pungens</i> Grunow	+++	+++	+++	+++
216	<i>N. pungens</i> v. <i>atlanticum</i> Grunow		+	++	+++
217	<i>N. seriata</i> Cleve		+		
218	<i>N. sigma</i> (Kutz) W.Smith		+		
219	<i>N. vitrea</i> Normann		+		
220	<i>N. sp</i>	+++	+++	+++	+++
221	<i>Pinularia ambigua</i> Cleve		+		
222	<i>P. cruciformis</i> (Donkin) Cleve			+	
223	<i>P. rectangulata</i> (Gregory) Rabenhorst		+		+
224	<i>Planktoniella sol</i> (Wallich) Schutt	++	+++	++	+
225	<i>Pleurosigma affine</i> Grunow	++	+++	+	+++
226	<i>P. angulatum</i> (Quekett) Smith	+	+	+	+
227	<i>P. formosum</i> W. Smith	+++	+	++	+++
228	<i>P. naviculaceum</i> Brebisson	+	++	+++	+++
229	<i>P. normanii</i> Ralfs		+		
230	<i>P. pelagicum</i> Peragallo	+++	++	++	+++
231	<i>P. rectum</i> Donkin	+	++	++	+++
232	<i>Pseudocunotia doliolus</i> (Wallich) Grunow		++	++	+
233	<i>Pyxidicula weyprechtii</i> Grunow		+	+	
234	<i>Rhizosolenia acuminata</i> (Peragallo) Gran	+	+	+	++
235	<i>R. alata</i> Brightwell	++	++	+++	+
236	<i>R. alata</i> f. <i>curvirostris</i> Gran	+		+	
237	<i>R. alata</i> f. <i>genuina</i> Gran	++	+	++	+++
238	<i>R. alata</i> f. <i>gracillima</i> Cleve	+++	+++	+++	+++
239	<i>R. alata</i> f. <i>indica</i> (Peragallo) Ostensfeld	++	++	+	+++
240	<i>R. alata</i> f. <i>inermis</i> (Caster.)	+			
241	<i>R. bergonii</i> Peragallo	+++	+++	+++	+++
242	<i>R. calca-avis</i> M. Schultze	+++	+++	+++	+++
243	<i>R. castracanei</i> Peragallo	++	+	++	++
244	<i>R. clevei</i> Ostensfeld	++	++	++	++
245	<i>R. cochlea</i> Grunow	+		+	+
246	<i>R. crassispina</i> Schroder	++	++	+	++
247	<i>R. cylindrus</i> Cleve	+++	+++	++	++
248	<i>R. delicatula</i> Cleve	+	+	+	+
249	<i>R. fragilissima</i> Bergon	+++	++	++	+++
250	<i>R. hebetata</i> f. <i>semispina</i> (Hensen) Gran	+++	+++	+++	++
251	<i>R. hyalina</i> Ostensfeld	++	++	++	
252	<i>R. imbricata</i> Brightwell	++	+++	+++	+++
253	<i>R. imbricata</i> v. <i>shrubssolei</i> (Cleve) Schroder	+++	+	+	++



Table 1. ( Continued).

No.	Species	A	B	C	D
<b>Bacillariophyta</b>					
252	<i>R. imbricata</i> Brightwell	++	+++	+++	+++
253	<i>R. imbricata</i> v. <i>shrubsolei</i> (Cleve) Schroder	+++	+	+	++
254	<i>R. robusta</i> Norman	+++	++	++	+++
255	<i>R. setigera</i> Brightwell	+++	++	++	+++
256	<i>R. stolterfothii</i> Peragallo	+++	+++	+++	+++
257	<i>R. styliformis</i> Brightwell	++	+++	+++	+++
258	<i>R. styliformis</i> v. <i>latissima</i> Brightwell	+++	+++	++	++
259	<i>R. styliformis</i> v. <i>longispina</i> Hustedt	+	+	+	+++
260	<i>Schrodella delicatula</i> (Peragallo) Pavillard		+	+	+
261	<i>Skeletonema costatum</i> (Greville) Cleve	++	++	++	
262	<i>Stauroneis amphyoxys</i> Greyory				+
263	<i>Stephanopyxis palmeriana</i> (Greville) Grunow	+++	+	+	
264	<i>Stigmophora rostrata</i> Wallich	+	++	+	++
265	<i>S. turris</i> (Greville & Arnott) Ralfs				
266	<i>Streptotheca indica</i> Karsten		+	+	++
267	<i>S. thamesis</i> Shrubsole	+	++	+	+
268	<i>Suriella amoricana</i> Peragallo				+
269	<i>S. fastuosa</i> Ehrenberg	+	+	+	
270	<i>S. ovata</i> Kutzing			+	+++
271	<i>S. ovalis</i> Brebisson			+	
272	<i>S. smithii</i> Ralfs				+
273	<i>Synedra acus</i> v. <i>radians</i> Kutzing	+	+	+	
274	<i>S. gaillonii</i> (Bory) Ehrenberg			++	
275	<i>Thalassionema nitzschioides</i> Grunow	+++	+++	+++	+++
276	<i>Thalassiothrix delicatula</i> Cupp	+			
277	<i>T. frauenfeldii</i> Grunow	+++	+++	+++	+++
278	<i>T. longissima</i> Cleve & Grunow	+++	+++	+++	+++
279	<i>Thalassiosira condensata</i> (Cleve)	+		+	+
280	<i>T. nordens kioldii</i> Cleve	+	+	+	
281	<i>T. pacifica</i> Gran & Angst		+++	+++	+
282	<i>T. subtilis</i> (Ostenfeld) Gran	++	+++	+++	+++
283	<i>Trachyneis aspera</i> (Ehrenberg) Grunow	+++	++	+++	++
284	<i>Triceratium favus</i> Ehrenberg	+		+	+
285	<i>T. formosum</i> Brightwell		+	+	+
286	<i>T. pentacrinus</i> Wallich				+
287	<i>T. pentacrinus</i> f. <i>quadrata</i> Peragallo			+	+
288	<i>T. shadboldtianum</i> Grelle				+
<b>Pyrrophyta</b>					
289	<i>Amoebophyra ceratii</i> (Coppen) Cachon		+		
290	<i>A. fursimorme</i> Martin	+			
291	<i>Amphisolenia bidentata</i> Schroder	++	+++	+++	++
292	<i>A. globifera</i> Stein		+	+	
293	<i>A. palacotheroides</i> Kofoid			+	

**Table 1.** ( Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
294	<i>A. schauinslandii</i> Lemmermann		+	+	
295	<i>A. thrinax</i> Schutt		+	+	
296	<i>A. sp.</i>		+		
297	<i>Ceratium arcuatum</i> (Gouret) Pavillard		++	++	+
298	<i>C. areticum</i> (Ehrenberg) Cleve		+	+	
299	<i>C. arietinum</i> Cleve		+		
300	<i>C. belone</i> Cleve	+	+		
301	<i>C. bigelowii</i> Kofoid		+		
302	<i>C. breve</i> (Ostenfeld & Schmidt) Schroder	+++	+	+	+
303	<i>C. breve v. parallelum</i> (Schmidt) Jorgensen	+	+	+	
304	<i>C. breve v. curnultum</i> Jorgensen	+	+	+	
305	<i>C. bucephalum v. heterocamptum</i> Jorgensen	+	+		
306	<i>C. candelabrum</i> (Ehrenberg) Stein		+		
307	<i>C. candelabrum</i> (Ehrenberg) <i>v. dilatalum</i> (Gouret)		+	+	
308	<i>C. caricense</i> Gourret	+	++	++	+
309	<i>C. caricense v. volans</i> (Cleve) Jorgensen		+	+	+
310	<i>C. caricense</i> Gourret <i>v. volans f. ceylannicum</i> (Schroder) Jorgensen	+	++	+	
311	<i>C. cephalotum</i> (Lemmermann) Kofoid			+	
312	<i>C. contortum</i> (Gourret) Cleve	+	++	+	+
313	<i>C. contortum v. saltan</i> (Schroder) Jorgensen	+	+	+	++
314	<i>C. declinatum</i> (Karsten) Jorgensen	+	+		
315	<i>C. dens</i> Ostenfeld & Schmidt			+	
316	<i>C. digitatum</i> Schutt			+	
317	<i>C. extensum</i> (Gourret) Cleve	+++	+++	+++	++
318	<i>C. furca</i> (Ehrenberg) Claparede & Lachmann	+++	+++	+++	+++
319	<i>C. furca v. eugranum</i> Jorgensen	++	+	++	++
320	<i>C. fusus</i> (Ehrenberg) Duraidin	+	+	+	
321	<i>C. fusus v. seta</i> (Ehrenberg) Jorgensen	+	++	+	
322	<i>C. fusus</i> (Ehrenberg) <i>v. schuttii</i> Lemmerman	+	+		
323	<i>C. geniculatum</i> (Lemm.) Cleve		+		
324	<i>C. gibberum v. sinistrum</i> Gourret	+	+	+	
325	<i>C. hirundinella</i> O.F. Muller	+	+		
326	<i>C. horidum</i> (Cleve) Gran			+	
327	<i>C. humile</i> Jorgensen	+	+		
328	<i>C. incisum</i> (Karsten) Jorgensen		+	+	
329	<i>C. inflatum</i> (Kofoid) Jorgensen		+		
330	<i>C. inflexum</i> (Gourret) Kofoid		+		
331	<i>C. karsteinii v. robustum</i> Jorgensen	+			
332	<i>C. kofoidii</i> Jorgensen	+++	+++	+++	+++
333	<i>C. lamellicorne</i> Kofoid		+		
334	<i>C. longinum</i> Karsten		+	+	
335	<i>C. longipes</i> (Bailey) Gran		+		

Table 1. ( Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
336	<i>C. longirostrum</i> (Gourret) Jorgensen		+		
337	<i>C. lineatum</i> (Ehrenberg) Cleve	+		+	
338	<i>C. lunula</i> Schimper		+		
339	<i>C. lunula f. megaceros</i> Jorgensen	++	+		
340	<i>C. macroceros</i> (Ehrenberg) Vanholf	+++	+++	+	+
341	<i>C. macroceros</i> (Ehrenberg) v. <i>gallicum</i> (Kofoid) Jorgensen	+	+	++	++
342	<i>C. massiliense</i> (Gourret) v. <i>armatum</i> (Karsten) Jorgensen	+			
343	<i>C. nipponicum</i> Okamura		+		
344	<i>C. palaeotheroides</i> Kofoid			+	
345	<i>C. Palmatum</i> (Schroder) Schroder			+	
346	<i>C. palmatum</i> (Schroder) v. <i>ranipes</i> (Cleve) Jorgensen			+	
347	<i>C. paradoxides</i> Cleve		+		
348	<i>C. pavillardii</i> Jorgensen	+			
349	<i>C. pennatum</i> Kofoid	+	+		
350	<i>C. pennatum</i> Kofoid f. <i>falcata</i> Kofoid	+	+		
351	<i>C. pennatum</i> Kofoid f. <i>propria</i> Kofoid	+	+	+	
352	<i>C. pennatum</i> Kofoid v. <i>scapiforme</i> (Kofoid) Jorgensen	+	+	+	
353	<i>C. pentagonum</i> Gourret	+++	+++	++	+
354	<i>C. platicorne</i> Won Daday		+		
355	<i>C. pulchellum</i> Schroder		+	+	
356	<i>C. reticulatum</i> (Pouchet) Cleve		+		
357	<i>C. reticulatum</i> (Pouchet) v. <i>spiralis</i> (Kofoid) Jorgensen	+	++		
358	<i>C. schroderi</i> Schroder	+	+		
359	<i>C. schunidti</i> Jorgensen		+		
360	<i>C. strictum</i> (Okamura & Niokikawa) Kofoid	+++	++	++	++
361	<i>C. sumatranum</i> (Karsten) Jorgensen		+	+	
362	<i>C. tenue</i> (Ostenfeld & Schmidt) Jorgensen		+		
363	<i>C. tenue f. inclinatum</i> (Kofoid) Jorgensen	+			
364	<i>C. teres</i> Kofoid			++	
365	<i>C. trichoceros</i> (Ehrenberg) Kofoid	+++	+++	+++	+++
366	<i>C. tripos f. atlanticum</i> Ostenfeld	+	+		
367	<i>C. tripos f. balticum</i> Schutt		+		
368	<i>C. tripos var. neglecta</i> (Ostenfeld) Paulsen		+		
369	<i>C. tripos typica</i> (O.F. Muller) Nitsch	+	+		
370	<i>Ceratocorys horrida</i> Stein		++	+	
371	<i>Cladopsis brachiolum</i> (Stein) Pavillard	+	+	+	
372	<i>Cochlodinium pellucidum</i> Lohmann	+			
373	<i>Corythodinium globosum</i> (Kofoid)		+		
374	<i>C. compressum</i> (Kofoid)		+		
375	<i>Dinophysis acuta</i> Ehrenberg		+		
376	<i>D. diegens</i> Kofoid v. <i>caudata</i> Pavillard	+	+		
377	<i>D. exigua</i> Kofoid & Skogsberg		+		
378	<i>D. expulsa</i> Kofoid & Miche		+	+	

Table 1. ( Continued).

No.	Species	A	B	C	D
	<b>Pyrrophyta</b>				
379	<i>D. hastata</i> Stein		+	+	
380	<i>D. homuculus</i> Stein	+++	+	+	
381	<i>D. intenmedia</i> Pavillard			+	
382	<i>D. ovum</i> Schutt		+		
383	<i>D. parvula</i> (Schutt) Balech			+	
384	<i>D. schuttii</i> Murrays & Whitting		+		
385	<i>D. rapa</i> (Stein) Abe		+		
386	<i>Diplopsalis lenticulata</i> Berg f. <i>asymmetrica</i> (Mang) Steid., Davis & Will.			+	
387	<i>Diplopsalopsis</i> sp.		+		
388	<i>Distephanus speculatum</i> v. <i>octonarium</i> (Ehrenberg) Jorgensen		+++	++	+
389	<i>Glenodium danicum</i> Paulsen	+	+		
390	<i>G. apiculata</i> (Penard) Entz.			+	
391	<i>G. gymnodinium</i> Pernard	+	+		
392	<i>Gonyaulax polygramma</i> Stein		+		
393	<i>G. heighleii</i> (Bailey) Ostenfeld		+	+	+
394	<i>G. kofoidii</i> Pavillard		+		
395	<i>G. levanderi</i> Lemmermann		+		
396	<i>G. pacifica</i> Kofoid			+	
397	<i>G. polyedra</i> Stein	+	+		
398	<i>G. spinifera</i> (Clap & Lachm.) Dies			+	
399	<i>G. triacantha</i> Jorgensen		+		
400	<i>G. turbynaei</i> Murray & SW		+		
401	<i>Gonyodoma ostenfeldii</i> Paulsen		+		
402	<i>Gymnodinium abbreviatum</i> Kofoid & Swezy		+	+	
403	<i>G. crassum</i> Pouchet			+	
404	<i>G. gacile</i> Bergh	+	+		
405	<i>G. heterostriatum</i> Kofoid & Swezy		+		
406	<i>G. lohmanni</i> Paulsen		+	+	+
407	<i>G. sp</i>		+	+	+
408	<i>G. spirale</i> (Bergh) Kofoid & Zwezy		+		
409	<i>G. vestifici</i> Schuft		+		
410	<i>Histioneis hippoperoides</i> Kofoid & Mich			+	
411	<i>H. mitchellana</i> Murray & whitting			+	
412	<i>H. pulchra</i> Kofoid			+	
413	<i>Mesocena polymorpha</i> Ehrenberg				
414	<i>M. polymorpha</i> v. <i>bioctonaria</i> (Ehrenberg) Lemmermann		+	+	
415	<i>Murrayella punctata</i> (Cleve) Kofoid		++	+	
416	<i>Ornithocercus heteroporus</i> Kofoid		+	+	
417	<i>O. magnificus</i> Stein		++	+	
418	<i>O. serratus</i> Kofoid		+	+	
419	<i>O. splendidus</i> Stein	++	++	+	

**Table 1.** (Continued).

No.	Species	A	B	C	D
Pyrrophyta					
420	<i>O. steinii</i> Murray & Whitting		+		
421	<i>O. quadratus</i> Schutt	+	+	+	
422	<i>Oxytoxum diplocunus</i> Stein		+	+	
423	<i>O. gladiolus</i> Stein		+		
424	<i>O. laticeps</i> Schiller			+	
425	<i>O. milneri</i> Murray & Whitting		+	+	
426	<i>O. nanum</i> Halldal		+		
427	<i>O. parvum</i> Schiller		+		
428	<i>O. reticulatum</i> (Stein) Schutt		+	+	
429	<i>O. scolopax</i> Stein		++	+++	
430	<i>O. subulatum</i> Kofoid		+		
431	<i>O. tessellatum</i> (Stein) Schutt		+	+	
432	<i>Parahistioneis para</i> Murray & White		+	+	
433	<i>Peridinium abei</i> Pauls		+		
434	<i>P. achromaticum</i> Levander		+		
435	<i>P. balticum</i> (Levander) Lemmermann		+		
436	<i>P. breve</i> Paulsen		++	+	
437	<i>P. brochii</i> Kofoid & Swezy	+	+		
438	<i>P. cantenatum</i> Levander		+		
439	<i>P. cerasus</i> Pauls	+++	+++	+++	+++
440	<i>P. clavus</i> Abe	+	+		
441	<i>P. corniculum</i> Kofoid & Micher		+		
442	<i>P. crassipes</i> Kofoid	+	+		+
443	<i>P. curtipes</i> Jorgensen		+		
444	<i>P. decipiens</i> Jorgensen	+			
445	<i>P. depressum</i> Bailey		++		
446	<i>P. divergens</i> Ehrenberg	+	+		
447	<i>P. elegans</i> Cleve		+	+	
448	<i>P. Facoceros</i> Paulsen		+		
449	<i>P. faltipes</i> Kofoid	+	+		
450	<i>P. globulus</i> Stein			+	
451	<i>P. grande</i> Kofoid		+	+	
452	<i>P. hemispherium</i> Abe		+++	+++	+++
453	<i>P. heteracanthum</i> P. Dangeard		+		
454	<i>P. logipes</i> Karsten		+		
455	<i>P. majus</i> P. Dang		+		
456	<i>P. marukawai</i> Abe		+	+	
457	<i>P. oceanicum</i> Vanhoff	++	++	+	+
458	<i>P. oceanicum</i> v. <i>oblongum</i> (Aurivillius) Cleve	+++	+++	++	++
459	<i>P. orbiculare</i> Pauls	+	+		
460	<i>P. pallidum</i> Ostenfeld		+	++	+
461	<i>P. parahistioneis para</i> Murray & White		+		
462	<i>P. paradoxum</i> Gaarder			+	

**Table 1.** (Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
463	<i>P. parallelum</i> Broch	+	+		
464	<i>P. pentagonum</i> v. <i>depressum</i> Abe				
465	<i>P. quarnerense</i> (Schroder) Broch	+			
466	<i>P. rectum</i> Kofoid	+	+++	+++	++
467	<i>P. roseum</i> Paulsen		+		
468	<i>P. rotundata</i> Abe		++	+++	+
469	<i>P. sphaerium</i> Okamura		++	++	++
470	<i>P. spheroides</i> P. Dangeard		+++	+++	+++
471	<i>P. spiniferum</i> Schiller	+		++	+
472	<i>P. steinii</i> Jorgensen	+	+		
473	<i>P. temissimum</i> Kofoid		+		
474	<i>P. thorianum</i> Paulsen			+	
475	<i>P. trochoideum</i> (Stein) Lemmermann	+	+		
476	<i>P. sp.</i>			+	
477	<i>Phalacroma cuneus</i> Schutt			+	
478	<i>P. doryphorum</i> Stein		+	+	
479	<i>P. mitra</i> Schutt		++	++	
480	<i>P. parvulum</i> (Schutt) Jorgesen			+	
481	<i>P. porodicum</i> Stein		+++	+++	+
482	<i>P. rotundatum</i> (Claparede & Lachmann) Kofoid & Micherner		++	++	+
483	<i>P. umbonatum</i> Stein			+++	+
484	<i>Podolampas bipes</i> Stein			++	+
485	<i>P. palmipes</i> Stein	+++	+++	+++	++
486	<i>P. spinifera</i> Okamura	++	+++	+++	+
487	<i>Pronoctiluca pelagica</i> Fabre-Domergue			+	
488	<i>Prorocentrum compressum</i> (Bailey) Abe' & Dodge			+	
489	<i>P. cordatum</i> (Ostenfeld) Dodge			+	
490	<i>P. gracile</i> Schutt		+		
491	<i>P. lenticulatum</i> (Matzenauer)		+	+	
492	<i>P. micans</i> Ehrenberg	++	+	+	
493	<i>P. minimum</i> (Pavillard) Schiller			+	
494	<i>P. pyriforme</i> (Schiller) Hasle		+	+	
495	<i>P. rostatum</i> Stein			+	
496	<i>P. scutelum</i> Schroder			+	
497	<i>Protoceratium reticulatum</i> (Clap & Lachm.) Butschli			+	
498	<i>Pyrocystis fusiformis</i> Murray		++	+	+
499	<i>P. hamulus</i> Cleve v. <i>inaequalis</i> Schroder	+	+		
500	<i>P. lunula</i> Schutt	+	++	+	
501	<i>P. noctiluca</i> Murray	+++	+++	++	+
502	<i>P. obtusa</i> Pavillard		+	+	+
503	<i>P. robusta</i> Kofoid		+		
504	<i>Pyrophacus horologicum</i> Stein	++	++	++	++

**Table 1.** (Continued).

No.	Species	A	B	C	D
	Pyrrophyta				
505	<i>Pseudoamphiprora stauroptera</i> (Baley) Cleve		+		
506	<i>Scripstella trochoidea</i> (Stein) Balech		+++	+++	+++
507	<i>Triposolenia bicornis</i> Kofoid		+		+
508	<i>Warnowia schuttii</i> (Kofoid & Swezy) Schiller			+	

### Phytoplankton abundance

Phytoplankton densities in the surface layer were high abundance in the coastal area (A, B, C and D). The highest cell count was 204,342 cells/l found at the station 57 in the area D; 185,258 cells/l at the station 3 in the area A; 62,420 cells/l at the station 37 in the area C.

At the station 10 in the off - shore of area B, the highest cell count was 147,186 cells/l [Table2, Fig.2].

Average total cell number of phytoplankton in the same abundance which have been found in the area A and D 77,301 and 66,153 cells/l. In the area B and C phytoplankton abundance was mostly lower than that in area A and D - 11,287 and 8,585 cells/l (Table 3).

In general the distribution of phytoplankton was concentrated at the surface water layers and decreased at the deeper water layers [Fig. 2 -5].

The average of cell number of phytoplankton in the Vietnamese seawaters was 24,804 cells/l at the surface layer, follow up 3,226 cells/l and 1,264 cells/l at the 50m and 100m layer [Table 3].

It was observed that total cell number densities of Cyanophyta were concentrated at lower area A, upper area B and all area D.

In the upper area A, central and lower area B and C, total cell number densities of Cyanophyta were relatively poor. Its distribution was concentrated at the surface layer and at the same time densities decreased at the deeper water layers. [Fig. 6 - 8].

The average cell number of Cyanophyta, Bacillariophyta and Pyrrophyta in the different water layers of the Vietnamese sea waters and its areas are given in Table 3.

In the above mentioned table, the cell number is shown that total cell number densities of these phytoplankton were concentrated at the surface water layers and decreased clearly at the deeper water layers. Figures 6-14 are shown the abundance distribution of these phytoplankton at the different water layers.

Cell number abundance of Silicoflagellata was relatively poor in the Vietnamese sea water. *Dictyocha octonaria* was only appeared at some stations in the area B.

High cell number densities of *Dictyocha fibula* were found in the coastal areas A, B and C. The distribution of densities of this species at the different water layers in the Vietnamese sea waters were given in Figures from 15 to 17. These figures and Table 3 were shown that at the 50m water layer cell of number densities of this species was more abundant than at the other layers.

### Occurrence of dominant species.

In the Cyanophyta, Oscillatoria (principal of *O. erythraea*) presented at all the study parts from areas A to D with abundant number and the frequently dominant species. The relative abundance of the

Oscillatoria was 11.09 - 99.07 % of total phytoplankton number while other dominant species reached only 9.31 - 55.63 %.

*Bacteriastrum elongatum*, *Bellerochea malleus*, *Chaetoceros cinctus*, *Thalassionema nitzschioides* and *Thalassiothrix frauenfeldii* were dominant species only in some stations in the coastal region of area A, B and D [Table 4] and distribution of these dominant species was shown in Figure 18.

For Pyrrophyta, there was no high percentages of occurrence.

**Table 2.** Cell number density of phytoplankton at the surface layer in the Vietnamese sea waters (April - May 1999).

St.	cells/l	St.	cells/l	St.	cells/l	St.	cells/l
1	3,876	16	4,420	31	1,182	46	3,974
2	87,779	17	1,398	32	1,143	47	5,387
3	185,258	18	934	33	4,733	48	7,913
4	148,500	19	1,863	34	8,803	49	17,598
5	504	20	2,797	35	1,463	50	6,046
6	5,036	21	2,036	36	6,440	51	11,359
7	110,158	22	2,787	37	62,420	52	21,614
8	1,504	23	592	38	22,566	53	13,393
9	2,865	24	2,567	39	2,426	54	28,184
10	147,186	25	2,333	40	3,154	55	9,656
11	5,595	26	3,845	41	5,601	56	15,830
12	1,583	27	2,918	42	8,483	57	204,342
13	21,108	28	2,269	43	1,904	58	170,050
14	25,001	29	7,635	44	1,567		
15	1,443	30	786	45	4,806		

**Table 3.** Average cell number densities of phytoplankton in the different water layers in Vietnamese sea water (April - May 1999).

Area	Layer (m)	Cells/l				
		<i>Bacillariophyta</i>	<i>Pyrrophyta</i>	<i>Cyanophyta</i>	<i>Silicoflagellata</i>	<i>Total Phytoplankton</i>
A	0	42,001	446	34,853	1	77,301
	50	2,745	83	1,212	30	4,070
B	0	2,303	256	8,720	8	11,287
	50	1,838	199	1,715	9	3,760
	100	616	85	670	4	1,376
C	0	4,291	257	4,036	1	8,585
	50	769	114	1,392	5	2,280
	100	721	69	282	1	1,073
D	0	36,515	473	29,162	3	66,153
	50	1,040	93	3,115	4	4,251
Areas	0	12,011	305	12,484	4	24,804
	50	1,385	155	1,679	7	3,226
	100	655	79	527	3	1,264



**Table 4.** Average abundance of phytoplankton from 100m (or the upper bottom) to surface water layers in the Vietnamese Waters (April - May 1999).

St.	Total phyto. (cells/l)	Dominant species		Associated species	
		Species	(%)	Species	(%)
1	3,293	<i>Oscillatoria</i>	18.12	<i>Guinardia flaccida</i>	13.81
2	67,467	<i>Oscillatoria</i>	15.37	<i>Chaetoceros paradoxus</i>	6.31
3	146,990	<i>Bellerophcea malleus</i>	31.40	<i>Oscillatoria</i>	2.01
4	78,787	<i>Oscillatoria</i>	74.13	<i>Chaetoceros compressus</i>	5.75
5	2,487	<i>Thalassiothrix frauenfeldii</i>	9.74	<i>Oscillatoria</i>	9.41
6	3,981	<i>Oscillatoria</i>	72.79	<i>Climacodium bivoncavum</i>	4.19
7	56,210	<i>Oscillatoria</i>	98.04	<i>Bacteriastrum hyalinum</i>	0.22
8	1,391	<i>Oscillatoria</i>	62.91	<i>Climacodium bivoncavum</i>	7.66
9	2,941	<i>Oscillatoria</i>	69.57	<i>Climacodium bivoncavum</i>	6.71
10	59,981	<i>Oscillatoria</i>	99.07	<i>Podolampas palmipes</i>	0.11
11	2,586	<i>Oscillatoria</i>	88.84	<i>Peridinium cerasus</i>	1.53
12	1,371	<i>Oscillatoria</i>	74.76	<i>Thalassiosira subtilis</i>	3.63
13	22,020	<i>Thalassionema nitzschioides</i>	9.31	<i>Rhizosolenia styliformis</i> v. <i>latissima</i>	7.34
14	13,930	<i>Thalassionema nitzschioides</i>	11.43	<i>Asterionella japonica</i>	8.49
15	1,261	<i>Oscillatoria</i>	85.06	<i>Rhizosolenia calcar-avis</i>	2.55
16	1,929	<i>Oscillatoria</i>	74.30	<i>Thalassiothrix frauenfeldii</i>	3.05
17	1,418	<i>Oscillatoria</i>	34.38	<i>Thalassiothrix frauenfeldii</i>	5.71
18	2,491	<i>Bacteriastrum elongatum</i>	15.66	<i>Oscillatoria</i>	15.16
19	1,392	<i>Oscillatoria</i>	42.55	<i>Peridinium cerasus</i>	6.23
20	1,573	<i>Oscillatoria</i>	38.68	<i>Thalassiothrix frauenfeldii</i>	7.37
21	1,284	<i>Oscillatoria</i>	11.09	<i>Thalassiothrix frauenfeldii</i>	10.34
22	1,284	<i>Oscillatoria</i>	77.68	<i>Peridinium cerasus</i>	2.22
23	599	<i>Oscillatoria</i>	45.30	<i>Thalassiothrix frauenfeldii</i>	5.35
24	1,257	<i>Oscillatoria</i>	74.32	<i>Thalassionema nitzschioides</i>	1.86
25	2,102	<i>Oscillatoria</i>	39.02	<i>Thalassionema nitzschioides</i>	7.90
26	1,798	<i>Oscillatoria</i>	86.15	<i>Peridinium cerasus</i>	2.37
27	1,252	<i>Oscillatoria</i>	78.79	<i>Peridinium cerasus</i>	2.48
28	1,804	<i>Oscillatoria</i>	46.30	<i>Chaetoceros curvisetus</i>	4.08
29	4,740	<i>Oscillatoria</i>	77.44	<i>Peridinium cerasus</i>	1.61
30	579	<i>Oscillatoria</i>	31.38	<i>Thalassiothrix frauenfeldii</i>	7.98
31	622	<i>Oscillatoria</i>	53.20	<i>Peridinium cerasus</i>	7.88
32	546	<i>Oscillatoria</i>	72.20	<i>Peridinium cerasus</i>	6.49
33	3,548	<i>Oscillatoria</i>	87.05	<i>Chaetoceros tortissimus</i>	1.77
34	5,268	<i>Oscillatoria</i>	81.78	<i>Chaetoceros messanensis</i>	1.73
35	990	<i>Oscillatoria</i>	79.87	<i>Dactyliosolen mediterraneus</i>	4.61
36	6,857	<i>Thalassiothrix frauenfeldii</i>	15.75	<i>Oscillatoria</i>	14.29
37	41,452	<i>Nitzschia pungens</i>	6.53	<i>Chaetoceros diversus</i>	6.25
38	17,657	<i>Chaetoceros cinctus</i>	55.63	<i>Thalassionema nitzschioides</i>	8.27
39	1,925	<i>Oscillatoria</i>	70.40	<i>Thalassiothrix frauenfeldii</i>	4.57
40	1,986	<i>Oscillatoria</i>	94.29	<i>Dactyliosolen mediterraneus</i>	0.55
41	3,648	<i>Oscillatoria</i>	94.11	<i>Peridinium cerasus</i>	0.65

**Table 4.** (Continued).

St.	Total phyto. (cells/l)	Dominant species		Associated species	
		Species	(%)	Species	(%)
42	4,766	<i>Oscillatoria</i>	80.25	<i>Chaetoceros curvisetus</i>	1.71
43	2,026	<i>Oscillatoria</i>	50.86	<i>Thalassionema nitzschioides</i>	10.98
44	1,191	<i>Oscillatoria</i>	81.34	<i>Peridinium cerasus</i>	3.23
45	2,785	<i>Oscillatoria</i>	86.85	<i>Pleurosigma naviculaceum</i>	1.82
46	2,574	<i>Oscillatoria</i>	89.59	<i>Peridinium cerasus</i>	1.65
47	3,165	<i>Oscillatoria</i>	86.03	<i>Peridinium cerasus</i>	2.81
48	9,079	<i>Oscillatoria</i>	56.11	<i>Rhizosolenia calcar-avis</i>	8.71
49	22,248	<i>Oscillatoria</i>	32.84	<i>Chaetoceros laevis</i>	5.74
50	4,852	<i>Oscillatoria</i>	59.23	<i>Thalassiothrix frauenfeldii</i>	4.28
51	7,397	<i>Oscillatoria</i>	88.85	<i>Thalassiothrix frauenfeldii</i>	1.79
52	12,698	<i>Oscillatoria</i>	91.97	<i>Thalassiothrix frauenfeldii</i>	1.87
53	9,266	<i>Oscillatoria</i>	36.17	<i>Nitzschia paradoxa</i>	5.49
54	25,650	<i>Oscillatoria</i>	61.44	<i>Chaetoceros pseudocurvisetus</i>	3.55
55	6,792	<i>Oscillatoria</i>	80.70	<i>Gyrosigma spenceri</i>	1.06

### Species diversity indices

All species number at different water layers of each station were summed, total cell number of phytoplankton and number of each species at different water layers were summed and calculated in average of each station for calculating the species diversity indices [Table 5].

**Table 5.** Species diversity indices of phytoplankton in the Vietnamese sea waters (April - May, 1999).

St	Total species	Total number of individuals (cells/l)	Richness indices (R)	H'	J	H' <sub>max</sub>	Dv
1	117	3,293	2.04	4.97	0.72	6.87	3.58
2	110	67,467	0.42	5.20	0.76	6.78	3.95
3	190	146,990	0.50	3.24	0.43	7.57	1.39
4	109	78,787	0.39	2.07	0.31	6.77	0.64
5	101	2,487	2.03	5.28	0.79	6.65	4.17
6	87	3,981	1.38	2.21	0.34	6.44	0.75
7	90	56,210	0.38	0.25	0.03	6.49	0.01
8	61	1,391	1.64	2.66	0.44	5.93	1.17
9	64	2,941	1.18	2.33	0.39	6.00	0.91
10	89	59,981	0.36	0.12	0.02	6.48	0.002
11	97	2,586	1.91	1.07	0.16	6.60	0.17
12	106	1,371	2.86	2.12	0.31	6.73	0.66
13	137	22,020	0.92	5.48	0.77	7.10	4.22
14	129	13,930	1.09	5.52	0.79	7.01	4.36
15	89	1,261	2.51	1.40	0.22	6.48	0.31
16	104	1,929	2.37	2.15	0.32	6.70	0.69
17	132	1,418	3.51	4.52	0.64	7.04	2.89

**Table 5.** (Continued).

St	Total species	Total number of individuals (cells/l)	Richness indices (R)	H'	J	H' <sub>max</sub>	Dv
18	112	2,491	2.24	4.72	0.69	6.81	3.26
19	115	1,392	3.08	4.22	0.62	6.85	2.62
20	147	1,573	3.71	4.55	0.63	7.20	2.87
21	161	1,284	4.49	5.89	0.83	7.33	4.89
22	112	1,284	3.13	2.06	0.30	6.81	0.62
23	97	599	3.96	3.95	0.60	6.60	2.37
24	89	1,257	2.51	2.18	0.34	6.48	0.74
25	92	2,102	2.01	4.00	0.61	6.52	2.44
26	97	1,798	2.29	1.29	0.20	6.60	0.26
27	113	1,252	3.19	1.94	0.28	6.82	0.54
28	158	1,804	3.72	4.36	0.60	7.30	2.62
29	129	4,740	1.87	2.12	0.30	7.01	0.64
30	119	579	4.95	4.85	0.70	6.89	3.40
31	104	622	4.17	3.51	0.52	6.70	1.83
32	97	546	4.15	2.29	0.34	6.60	0.78
33	106	3,548	1.78	1.25	0.19	6.73	0.24
34	131	5,268	1.80	1.64	0.23	7.03	0.38
35	92	990	2.92	1.76	0.27	6.52	0.48
36	120	6,857	1.45	4.72	0.68	6.91	3.21
37	105	41,452	0.52	5.45	0.81	6.71	4.41
38	86	17,657	0.65	3.26	0.51	6.43	1.66
39	104	1,925	2.37	2.45	0.37	6.70	0.91
40	85	1,986	1.91	0.63	0.10	6.41	0.06
41	92	3,648	1.52	0.65	0.10	6.52	0.07
42	147	4,766	2.13	1.86	0.26	7.20	0.48
43	134	2,026	2.98	3.56	0.50	7.07	1.78
44	103	1,191	2.98	1.69	0.25	6.69	0.42
45	76	2,785	1.44	1.23	0.20	6.23	0.25
46	82	2,574	1.62	1.02	0.16	6.36	0.16
47	81	3,165	1.44	1.26	0.20	6.34	0.25
48	108	9,079	1.13	3.17	0.47	6.75	1.49
49	103	22,248	0.69	4.61	0.69	6.69	3.18
50	100	4,852	1.44	3.18	0.48	6.64	1.53
51	75	7,397	0.87	1.05	0.17	6.23	0.18
52	98	12,698	0.87	0.81	0.12	6.61	0.10
53	117	9,266	1.22	4.48	0.65	6.87	2.91
54	116	25,650	0.72	3.03	0.44	6.86	1.33
55	107	6,792	1.30	1.82	0.27	6.74	0.49
56	97	32,257	0.54	0.32	0.05	6.59	0.02
57	110	144,077	0.29	5.25	0.77	6.78	4.04
58	91	144,253	0.24	4.26	0.66	6.51	2.81
<b>Average</b>		<b>17,410</b>	<b>1.93</b>	<b>2.88</b>	<b>0.42</b>	<b>6.71</b>	<b>1.60</b>

High diversity indices H' of phytoplankton were found at the station No: 2, 5, 13, 14, 21, 37, and No 57, and corresponding value of these stations were 5.20, 5.28, 5.48, 5.52, 5.52, 5.45 and 5.25.

High evenness indices  $J$  of phytoplankton occurred at the stations No 2, 5, 13, 14, 21, 37 and No 57 which had corresponding value: 0.76, 0.79, 0.77, 0.79, 0.83, 0.81 and 0.77.

Lowest diversity indices of phytoplankton occurred at the station No 7, 10, 40, 41, 52 and No 56 corresponding value 0.25, 0.12, 0.63, 0.81 and 0.32.

Lowest evenness indices were found at the stations No 7, 10, 40, 41, 52 and 56 which had corresponding value 0.03, 0.02, 0.10, 0.10, 0.12 and 0.05.

As the above mention description, it showed that the change of indices were high.

Richness indices  $R$  reached high value in the station of area B and C.

Maximum diversity indices  $H'_{\max}$  were relatively stable in the range 5.93 - 7.57.

Value of diversity indices  $D_v$  were changed in the range from 0.002 at the station 10 to 4.89 at the station 21.

The average of species diversity indices of phytoplankton in the different areas of Vietnamese sea water were shown in the Table 6.

**Table 6.** Species diversity indices of phytoplankton in the different areas of the Vietnamese waters (April - May 1999).

Area	Total species	Total number of individuals (cells/l)	Richness indices (R)	Diversity indices (H')	Maximum diversity indices ( $H'_{\max}$ )	Evenness indices (J)	Diversity value ( $D_v$ )
A	271	51,316	1.02	3.32	6.80	0.48	2.07
B	387	5,984	2.51	3.17	6.73	0.46	1.84
C	320	6,517	2.03	2.49	6.67	0.37	1.21
D	218	53,570	0.74	2.85	6.71	0.42	1.67
Areas	508	17,410	1.93	2.88	6.71	0.42	1.60

### Discussion and Conclusion

1. According to the data from Nguyen Tien Canh (1996), the phytoplankton collected by Van Dorn water sampler were reacher than that by phytoplankton net [Table 7].

2. Tendency of distribution of phytoplankton of this cruise was similar to the distribution of phytoplankton in the Vietnamese seawaters in the past years.

3. Diversity indices and their application to aquatic studies were described by Washington (1994) and Metcalfe (1989) [in Mason (1995)]. The most widely used indices of diversity which were those based on the information theory, the most frequent measure was being used by the Shannon index which assumes that individuals are randomly sampled from an indefinitely large population:

$$H' = - \sum_{i=1}^s P_i \log P_i .$$

The diversity indices  $H'$  of phytoplankton is to show the occurred frequency at one of areas, it mainly related to the number that the character vietics of diversity phytoplankton had to relationship with the variation of number and of phytoplankton composition.

In order to have the index that reflected typical characteristic of diversity, Chen Qing Chao (1993) calculated diversity value  $D_v$  for tropical marine regions:

$$Dv = H' \cdot J \text{ or } Dv = H'^2 / \log_2(S)$$

And provided level of diversity in Table 8.

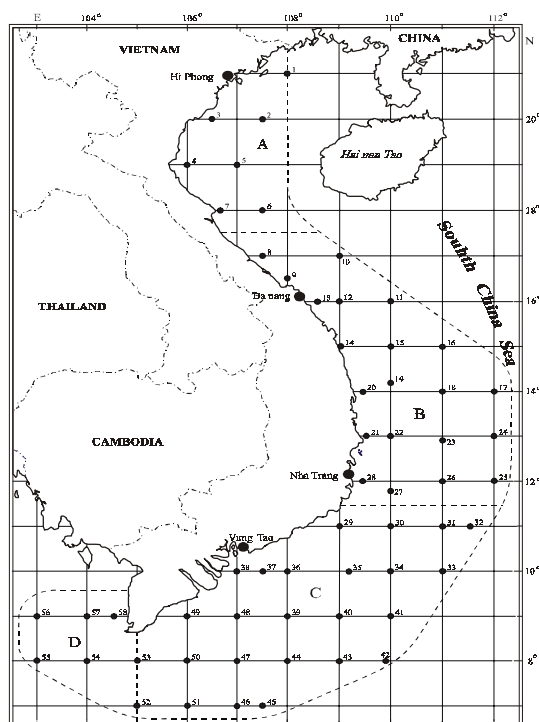
**Table 7.** Average cell number of Phytoplankton sampled by Phytoplankton net (1959 - 1986) (1) and by Van Dorn water sampler (1999) (2) in the different areas of the Vietnamese waters.

<b>Area</b> <b>Sampler</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<b>(1)</b>	1,926	437	827	5,549
<b>(2)</b>	51,316	5,984	6,517	53,570

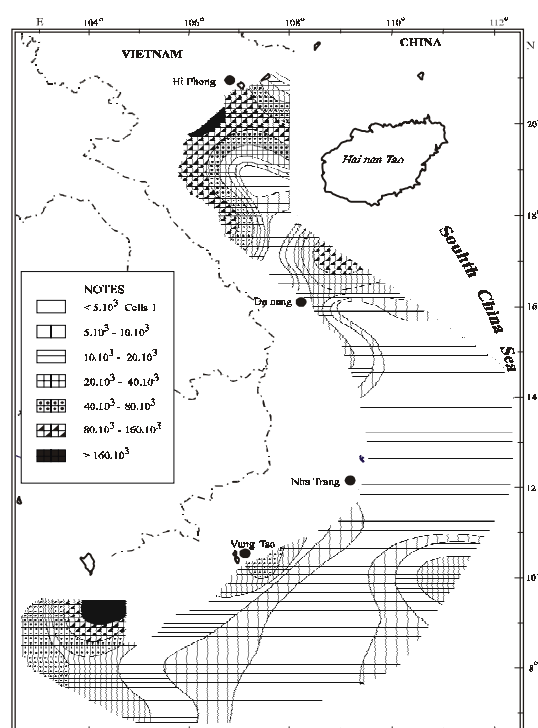
**Table 8.** Field of phytoplankton diversity value in Vietnamese waters.

<b>Value of phytoplankton diversity (Dv)</b>	<b>Level of phytoplankton diversity</b>	<b>Form of diversity</b>
> 3.5	Richness diversity	I
2.6 - 3.5	Rich diversity	II
1.6 - 2.5	Fair diversity	III
0.6 - 1.5	Normal diversity	IV
< 0.6	Low diversity	V

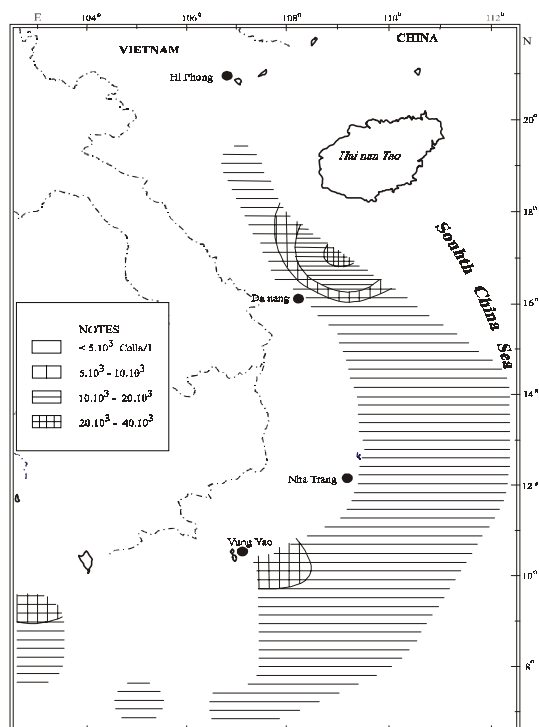
According to the above mentioned issue, the diversity value of area A reached 2.07 (form III), which was the fair diversity area, the other areas that were normal diversity were from 1.21 - 1.34 (form IV).



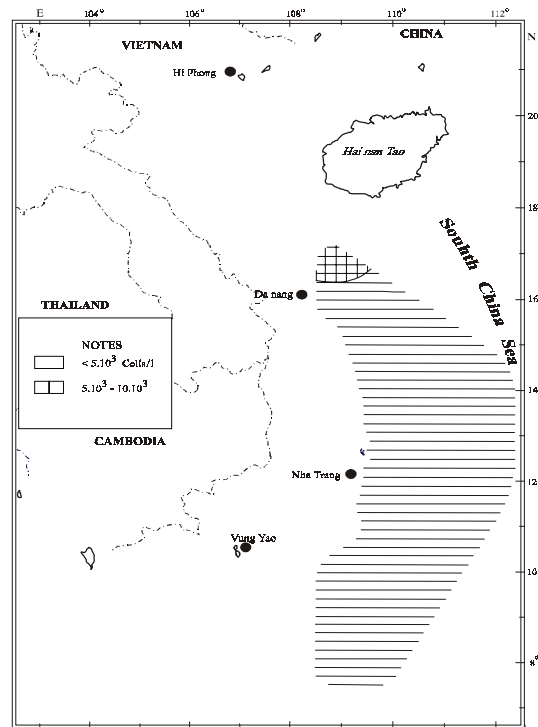
**Fig. 1.** Station system of collaborative research survey in the Vietnamese waters (April-May 1999).



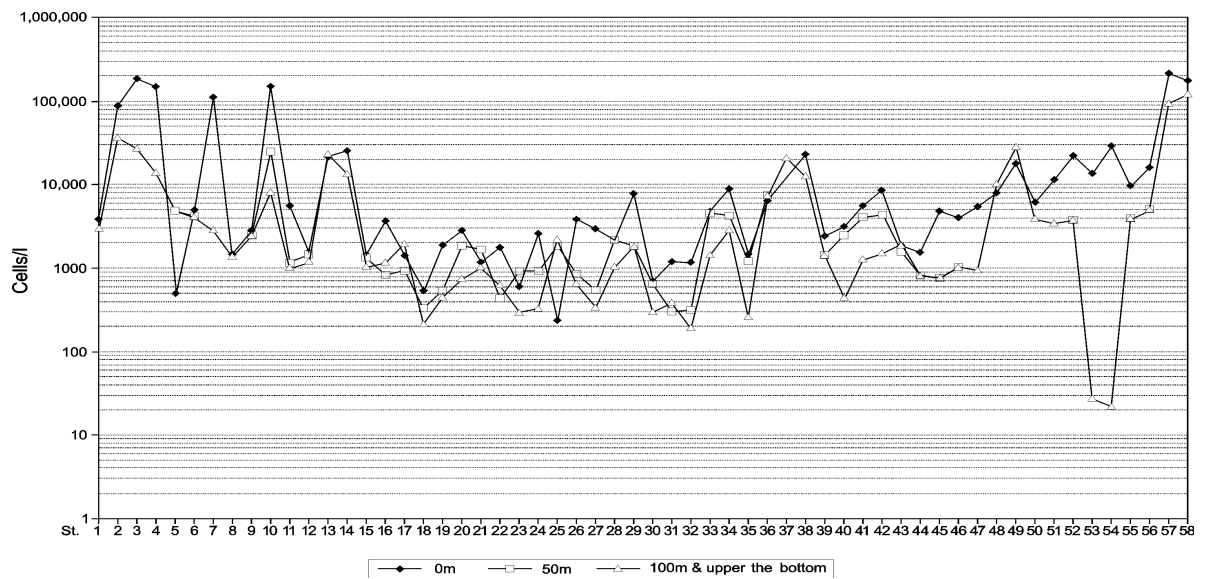
**Fig. 2.** Total phytoplankton density(cells/l) at the surface water layer in the Vietnamese waters (April-May, 1999).



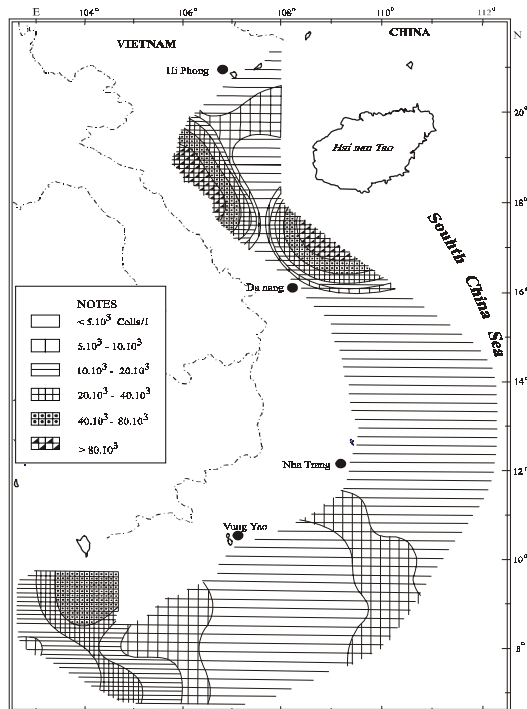
**Fig. 3.** Total phytoplankton density(cells/l) at the 50m water layer in the Vietnamese waters (April-May, 1999).



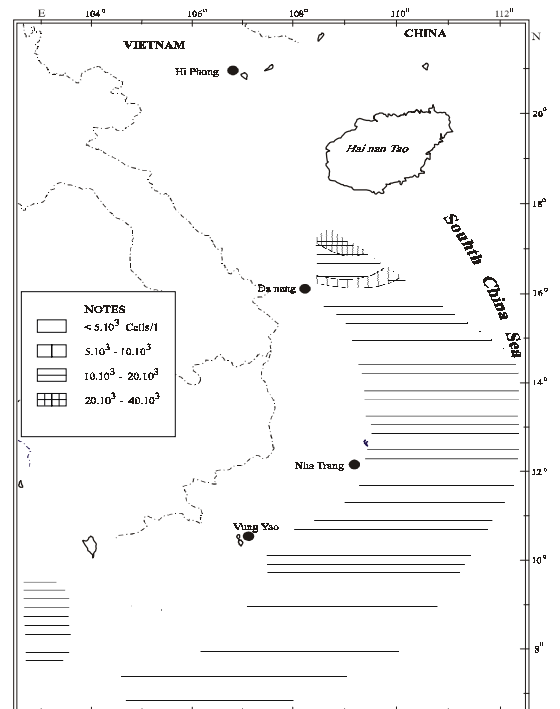
**Fig. 4.** Total phytoplankton density (cells/ l) at the 100m water layer in the Vietnamese waters (April-May, 1999).



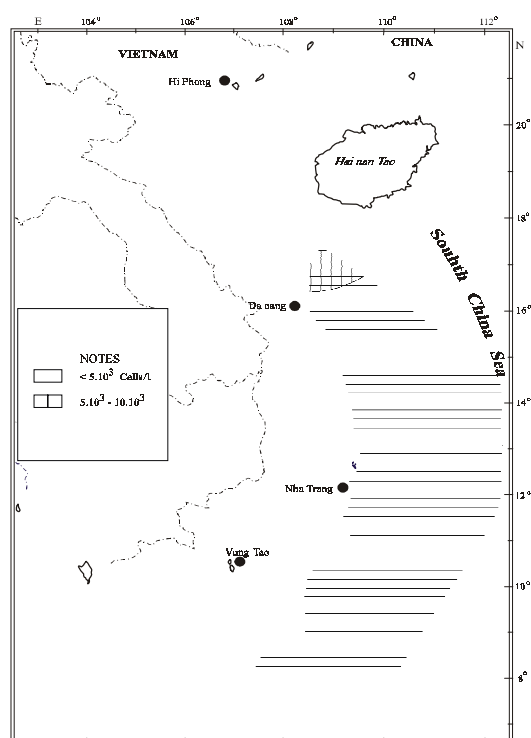
**Fig. 5.** Distribution of phytoplankton density at the different water layers in Vietnamese water (April-May, 1999).



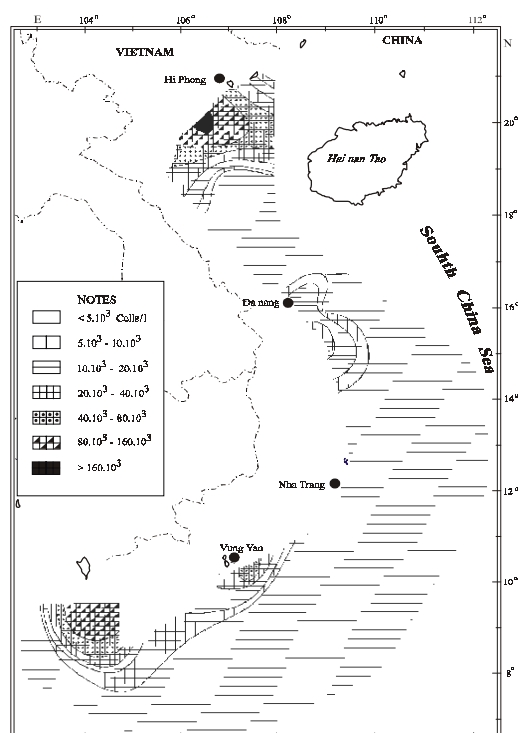
**Fig. 6.** Oscillatoria population density (cells/l) at the surface water layer in the Vietnamese waters (April-May, 1999).



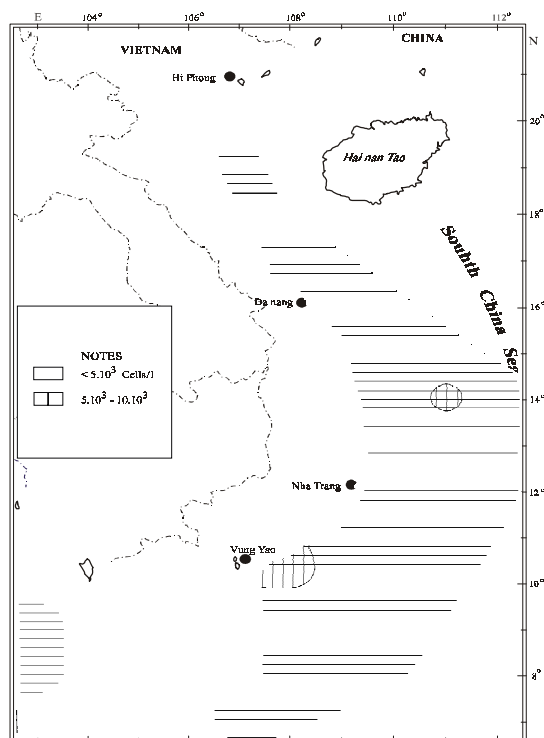
**Fig. 7.** Oscillatoria population density (cells/l) at the 50 m water layer in the Vietnamese waters (April-May, 1999).



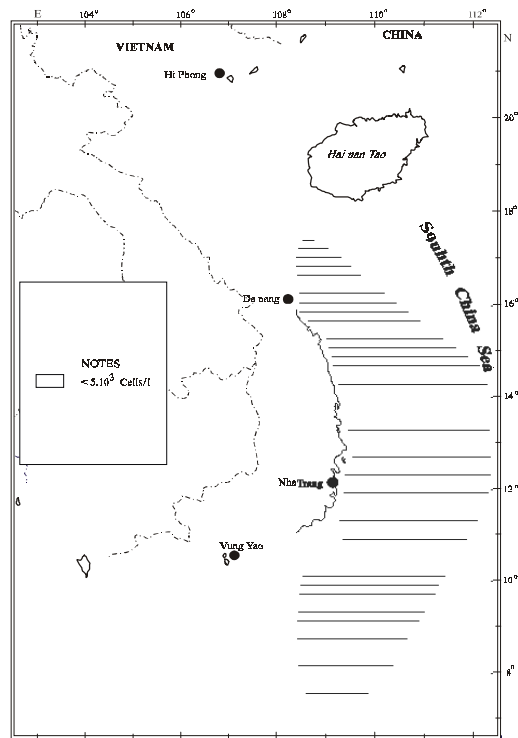
**Fig. 8.** *Oscillatoria* population density(cells/l)at the 100m water layer in the Vietnamese waters (April-May, 1999).



**Fig. 9.** *Bacillariophyta* population density(cells/l)at the surface water layer in the Vietnamese waters (April-May, 1999).

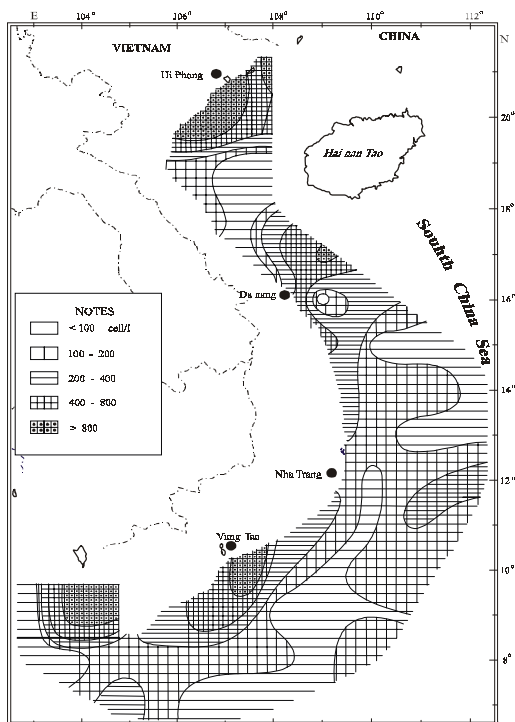


**Fig. 10.** *Bacillariophyta* population density (cell/l) at the 50m water layer in the Vietnamese waters (April-May, 1999).

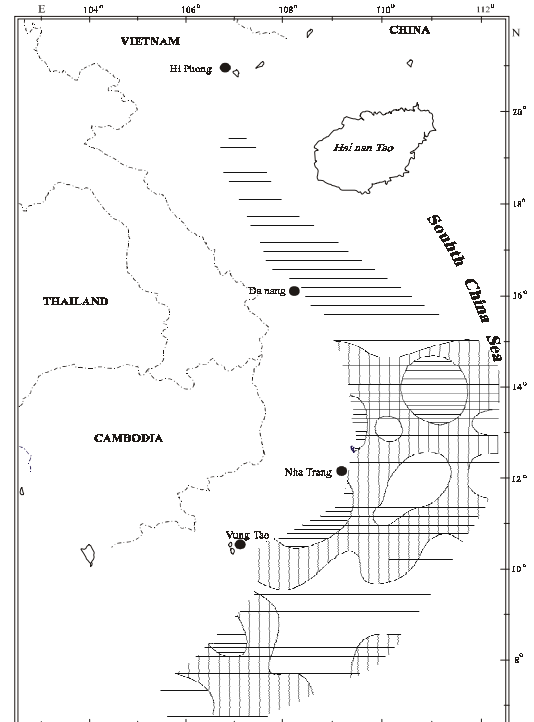


**Fig. 11.** *Bacillariophyta* population density(cell/l) at the 100m water layer in the Vietnamese waters (April-May, 1999).

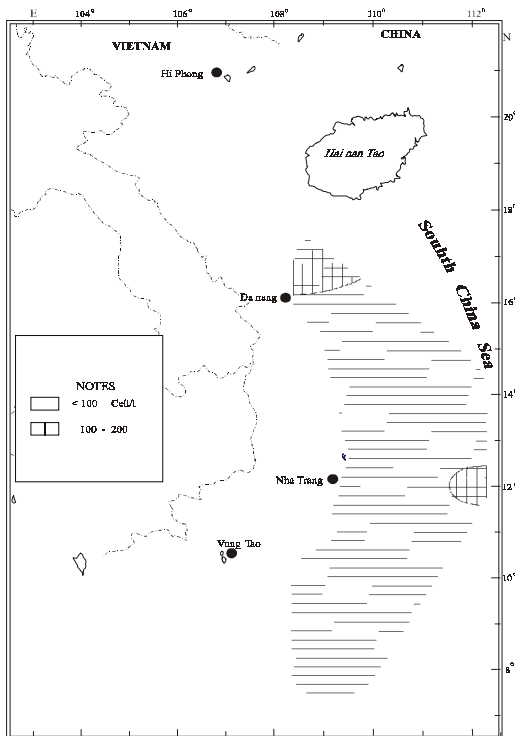




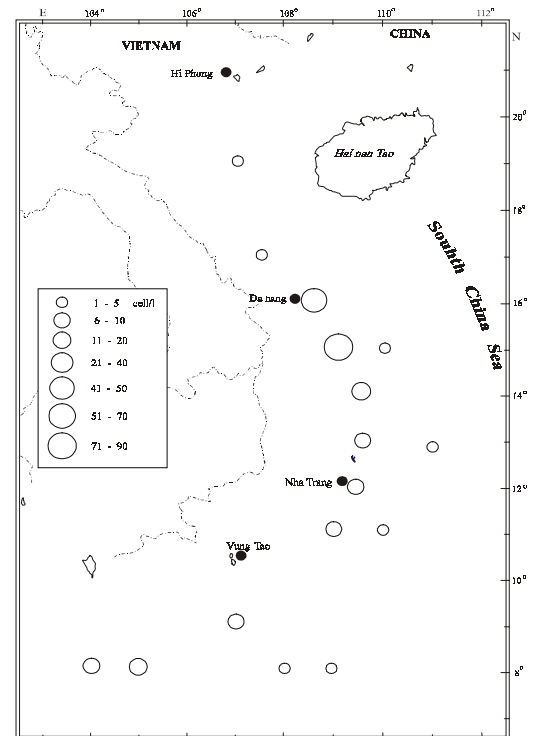
**Fig. 12.** Pyrophyta population density (cells/l) at the surface water layer in the Vietnamese waters (April-May, 1999).



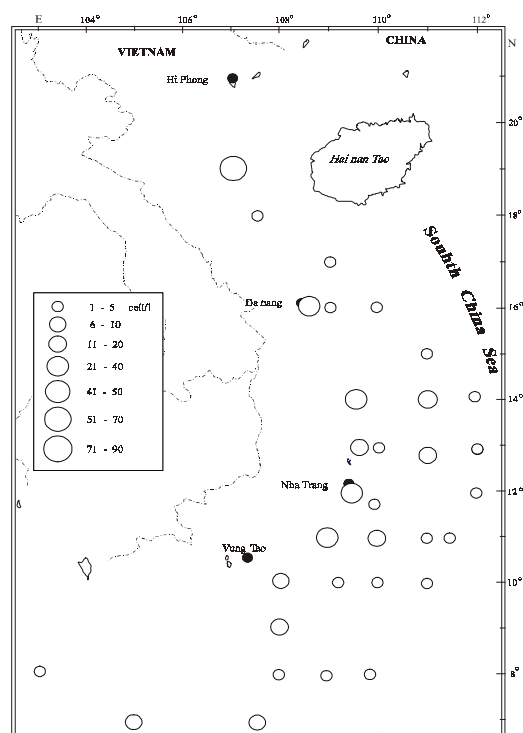
**Fig. 13.** Pyrophyta population density (cells/l) at the 50m water layer in the Vietnamese waters (April-May, 1999).



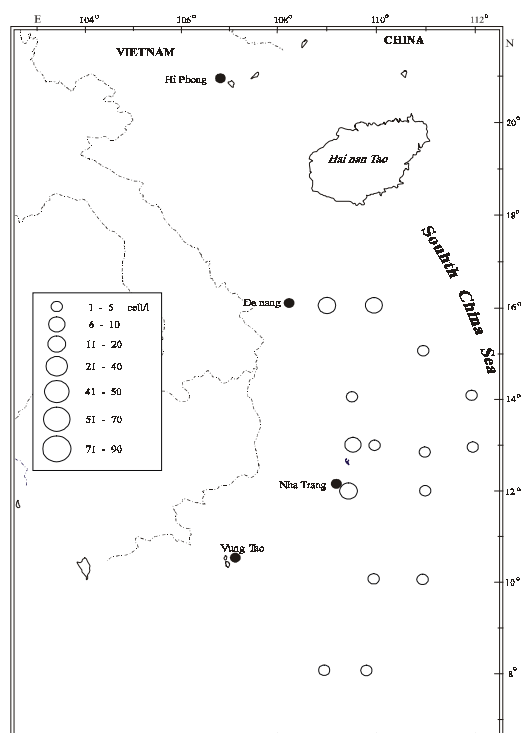
**Fig. 14.** Pyrophyta population density (cells/l) at the 100m water layer in the Vietnamese waters (April-May, 1999).



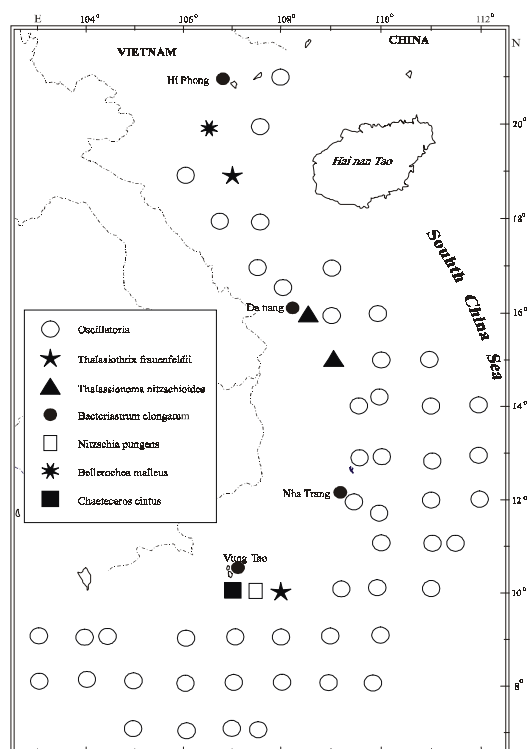
**Fig. 15.** Distribution *Dictyocha fibula* density (cells/l) at the surface water layer in the Vietnamese waters (April-May, 1999).



**Fig. 16.** Distribution *Dictyocha fibula* density (cells/l) at the 50 m water layer in the Vietnamese waters (April-May,1999).



**Fig. 17.** Distribution *Dictyocha fibula* density (cells/l) at the 100m water layer in the Vietnamese waters (April-May,1999).



**Fig. 18.** Dominant species in the Vietnamese waters (April-May,1999).

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